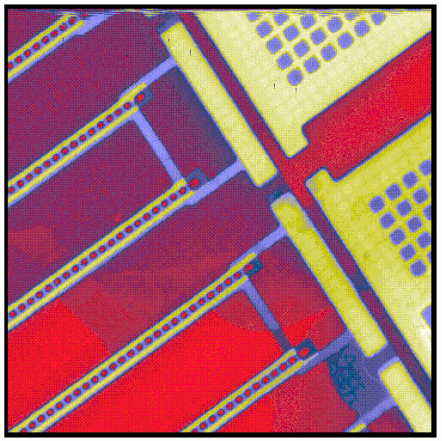
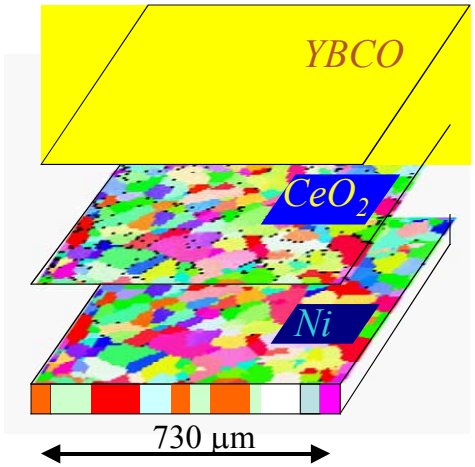


Science With Microbeams



APS Science Advisory Committee
Cross-Cut Review
January 21, 2004
Introduction, J. Murray Gibson

Purpose of the Review

- Science Advisory Committee does sector-by-sector reviews
- Cross-cut gives an important perspective
  - focus of review is retrospective (“where are we now”)
  - additional experts invited
- Report will advise APS on strengths and opportunities
- Session is open for healthy information exchange

How did we select the program?

- Current research programs involving x-rays focused to < 10μm
- Asked sectors for their best science
- Only one presentation per sector, due to time
  - Sectors included based on scale of activity
- Further information provided as backup
  - to be posted on the web

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(Murray Gibson)

10:45 a.m.: High-pressure geoscience at GSECARS
(Guoyin Shen - Sector 13)

11:15 a.m.: Earth and environmental science at the microscale level at GSECARS
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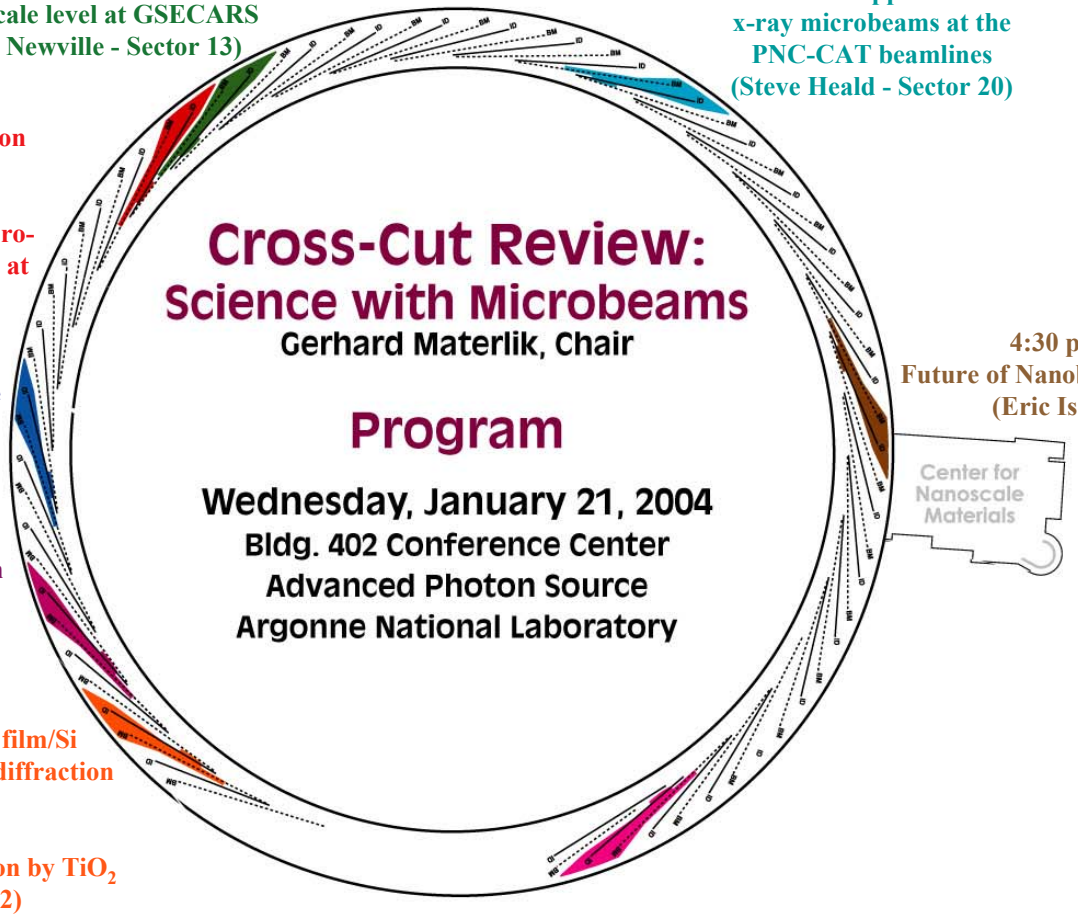

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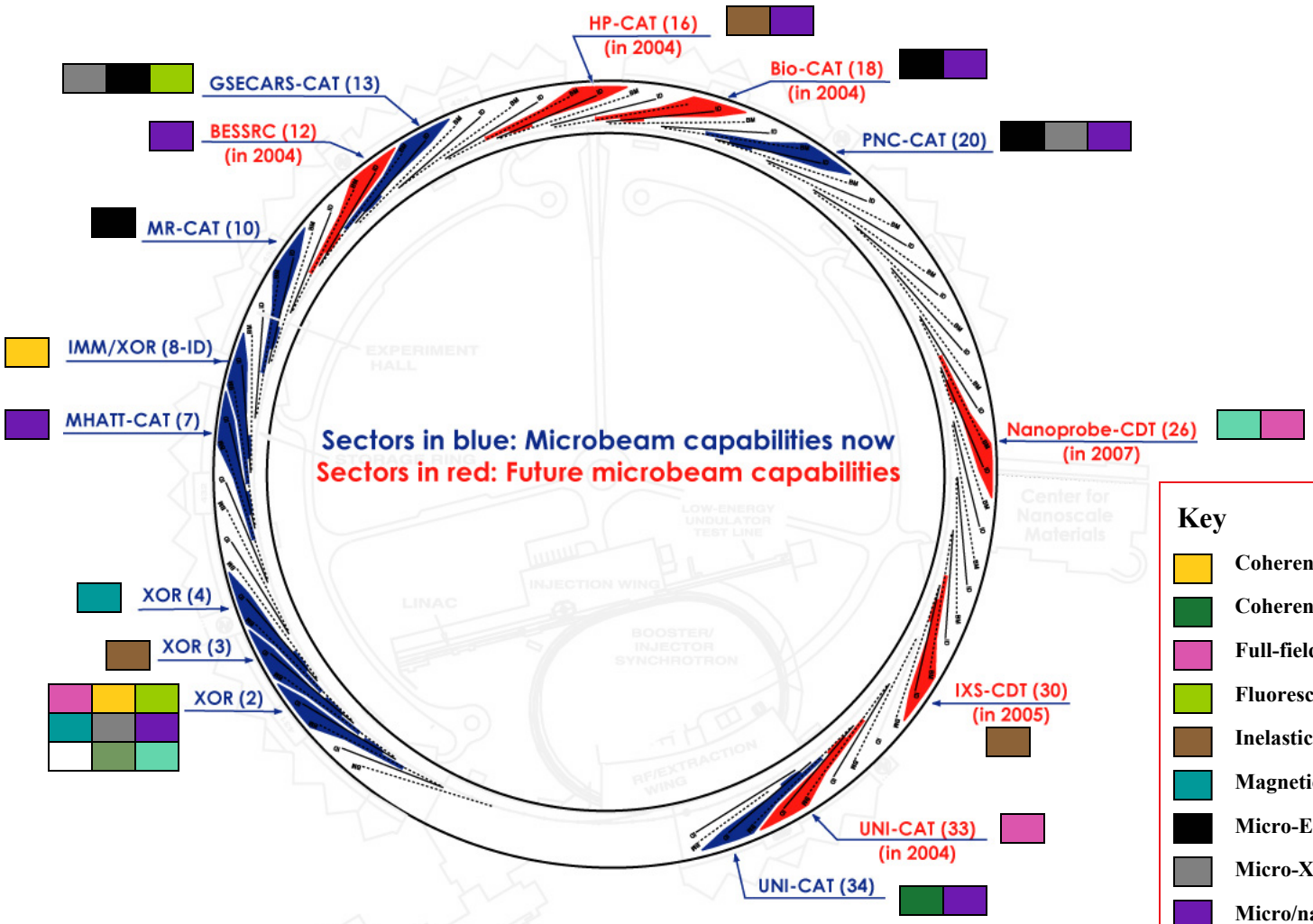
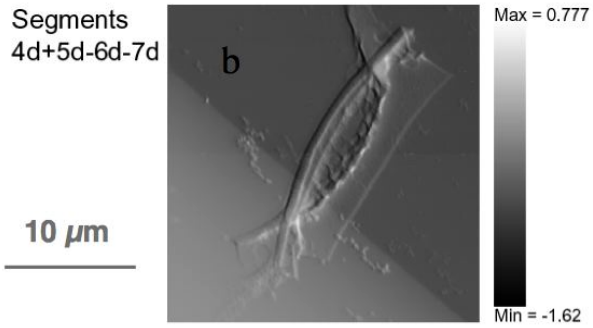
APS X-ray Microbeam Techniques



X-ray microbeam techniques in use at APS

Scanning transmission/DPC microscopy

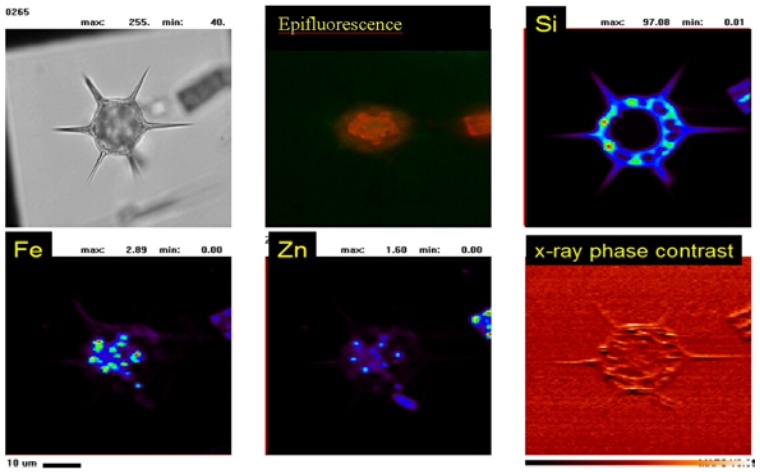
X-ray optics are used to form a microfocused spot on the sample, which is raster-scanned to form images in absorption and differential phase contrast modes. STXM is fast and can be combined with XANES as for SFXM.



Scanning differential phase contrast image of a diatom, taken with 1.8 keV x-rays at 2-ID-B.

Scanning fluorescence microscopy

X-ray optics are used to form a microfocused spot on the sample, which is raster-scanned to form images in x-ray fluorescence contrast. SFXM is highly sensitive to elemental makeup and chemical state information.

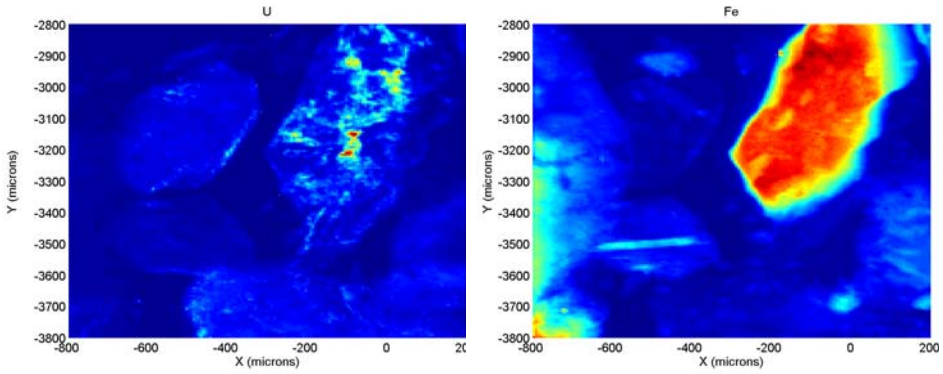


Visible light and epifluorescence micrographs, false-color SFXM element maps, and x-ray phase contrast image of a silicoflagellate from the Southern Ocean. Data from 2-ID-E.

X-ray microbeam techniques in use at APS

Micro-EXAFS

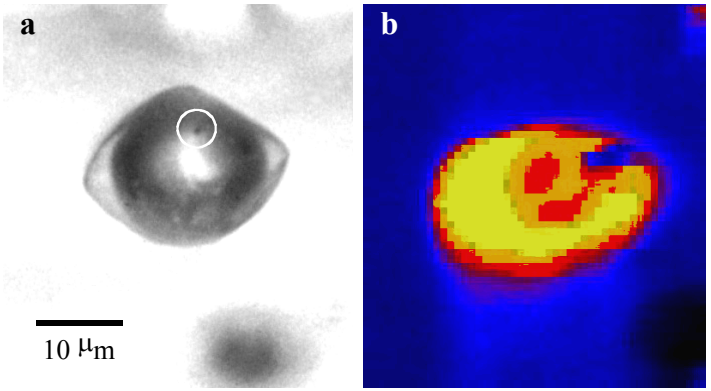
Similar to SFXM, but incident energy is scanned over a wide range to obtain extended x-ray absorption fine-structure spectra (usally fluorescence mode) at each sample point. Spectra are Fourier-inverted to discern atomic structure.



U and Fe fluorescence maps taken at 20-ID from a sediment thin section from beneath a leaking rad-waste storage tank at Hanford.

Micro-XANES

Similar to SFXM, but incident energy is scanned in fine steps to obtain x-ray absorption near-edge spectra (e.g. by fluorescence) at each sample point.



(a) Optical and (b) Cu K_a images of a vapor phase fluid inclusion in quartz taken at 13-ID, showing that Cu is uniformly distributed in the fluid phase. Cu K micro-XANES spectra show reversible changes in Cu oxidation with temperature. This may control speciation behavior during formation of important Cu deposits.

X-ray microbeam techniques in use at APS

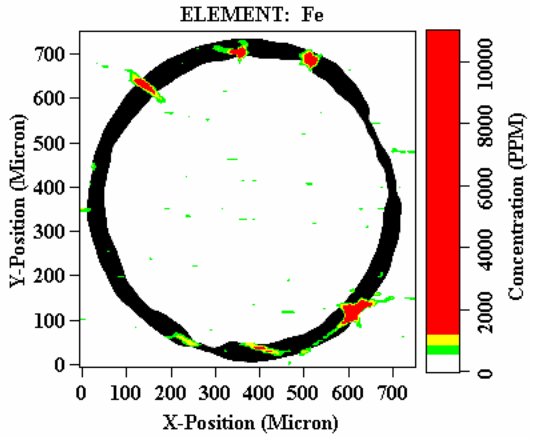
Full-field microscopy

High resolution x-ray optics are used to image the sample directly onto an array detector such as a CCD camera. Main advantages are speed and amenability to phase contrast methods.

Quantitative 3D reconstructions of the real part of the refractive index of a silicon atomic force microscope tip. Coherent full-field projections taken at 2-ID-B.

Fluorescence microtomography

Similar to SFXM, but sample is rotated through a large angular range to record many views of it. Projection data are filtered and reconstructed to form 3D images of the sample.

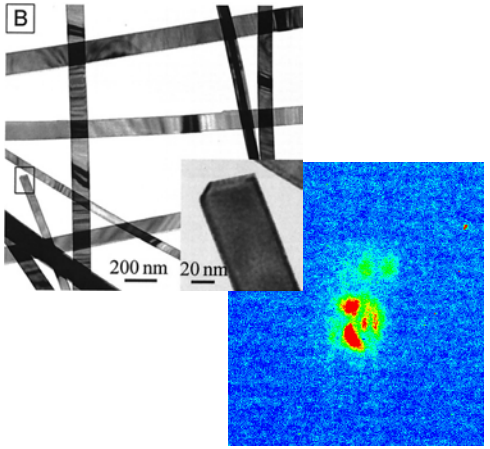


Reconstructed slice showing trace Fe content in a SiC nuclear fuel shell, using Fe K fluorescence microtomography data recorded at 2-ID-D.

X-ray microbeam techniques in use at APS

Micro/nanodiffraction

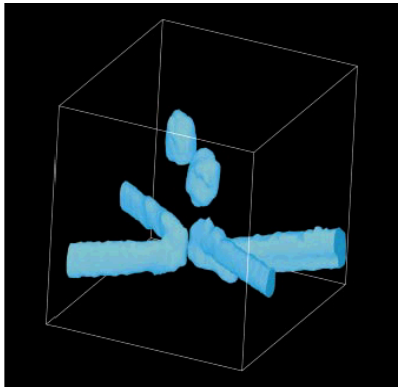
Microfocusing optics such as KB mirrors and zone plates are used to isolate specific sample regions and increase the x-ray flux density in diffraction experiments.



SEM images of Sn_2O_3 nanobelts. X-ray diffraction pattern from a 30 nm x 10 nm nanobelt, recorded at 2-ID-D.

Scanning nanotomography

Similar to STXM, but sample is rotated through a large angular range to record many views through it. Projection data are filtered and reconstructed to form 3D images of the sample.

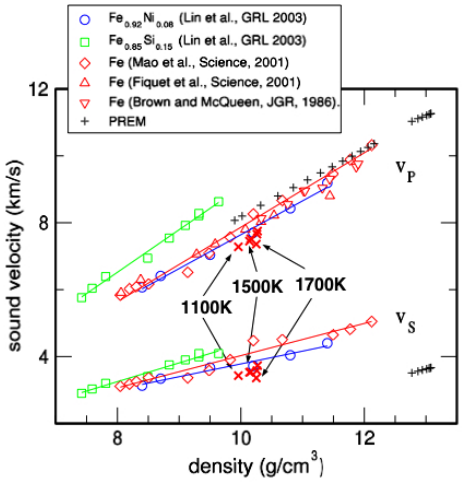


Reconstruction of 13 projections (1573 eV) through two-level chip sample, showing W vias and Al interconnects in $(8\ \mu m)^3$ volume. Data from 2-ID-B.

X-ray microbeam techniques in use at APS

Inelastic x-ray scattering

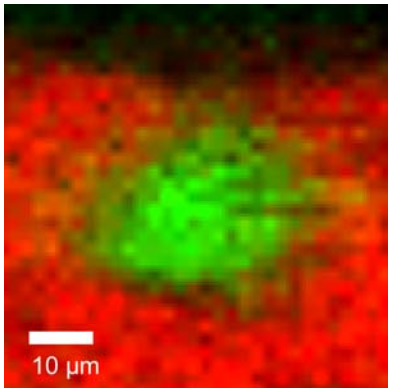
Microfocusing optics such as KB mirrors are used to increase the x-ray flux density on the sample in inelastic scattering experiments.



Temperature effect on sound velocitie s in iron at high pressure measured at room temperature (except red crosses) at 3-ID-B.

Magnetic microscopy

Similar to SFXM, but incident x-ray beam is linearly or circularly polarized to form images of the sample with magnetic charge contrast by absorption or diffraction methods.

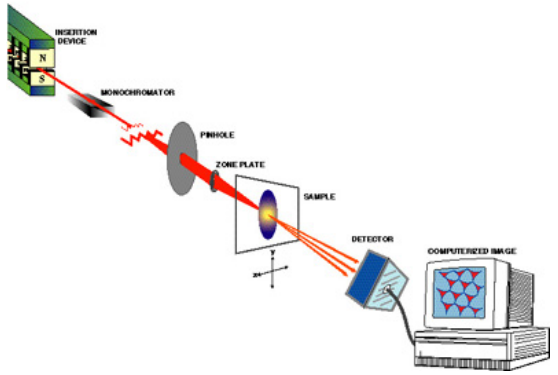


Magnetic diffraction contrast image of superposed (δ,0,1) (red) and (0,δ,1) (green) incommensurate reflections from spin density wave domains in a Cr single crystal at 110 K. Data recorded at 2-ID-D.

X-ray microbeam techniques in use at APS

Coherent scattering/speckle

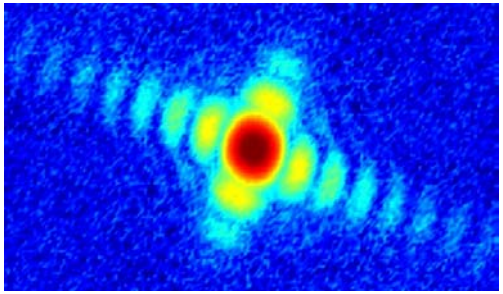
Microfocusing optics such as zone plates are used to tailor the x-ray beam phase space to the sample in coherent scattering and speckle experiments.



Coherent x-ray scattering experiment using zone plate microfopcusing optics, as at 2-ID and 8-ID.

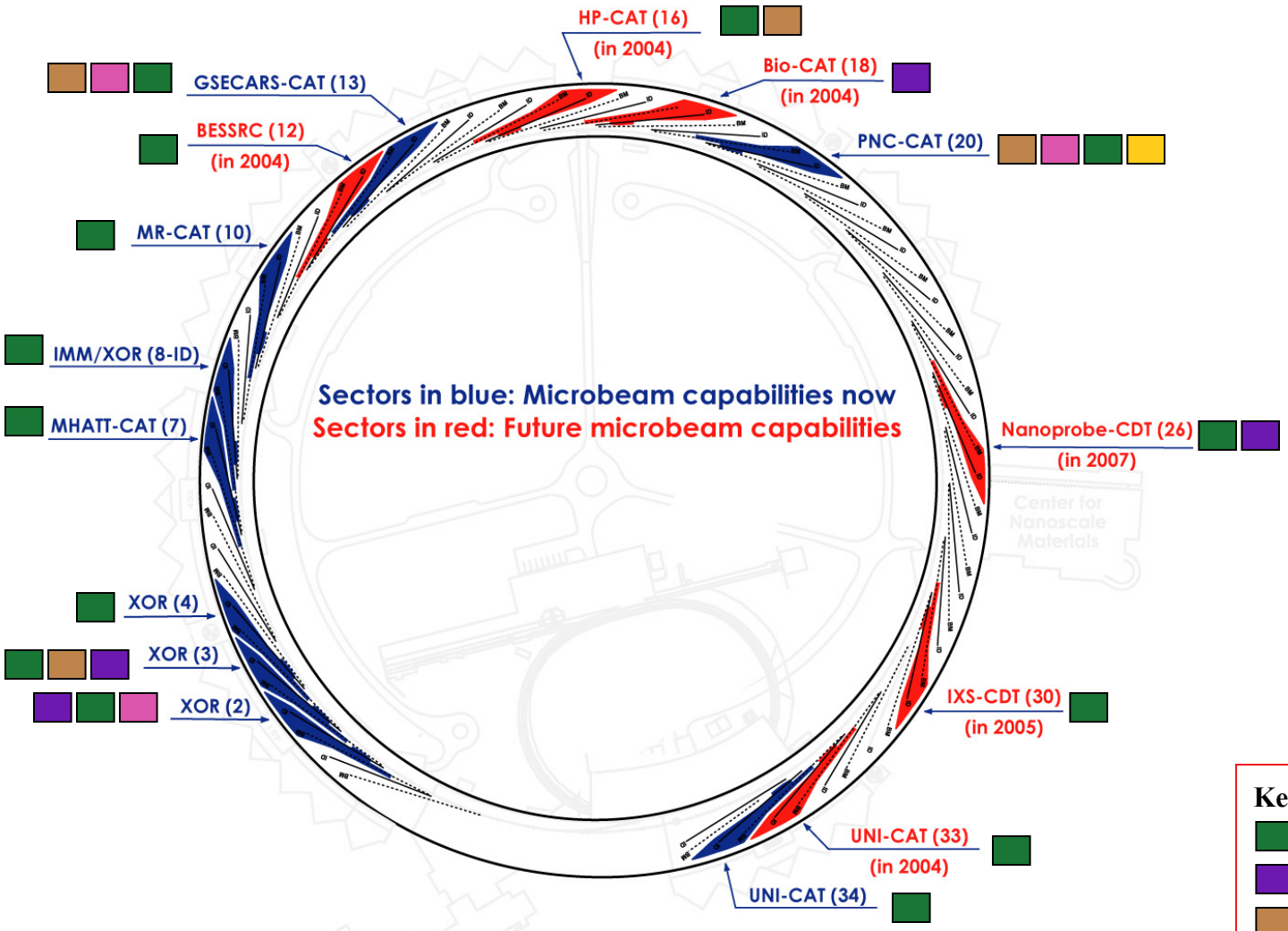
Coherent diffraction imaging

Microfocusing optics such as KB mirrors are used to increase the x-ray flux density on the sample in coherent diffraction imaging experiments.

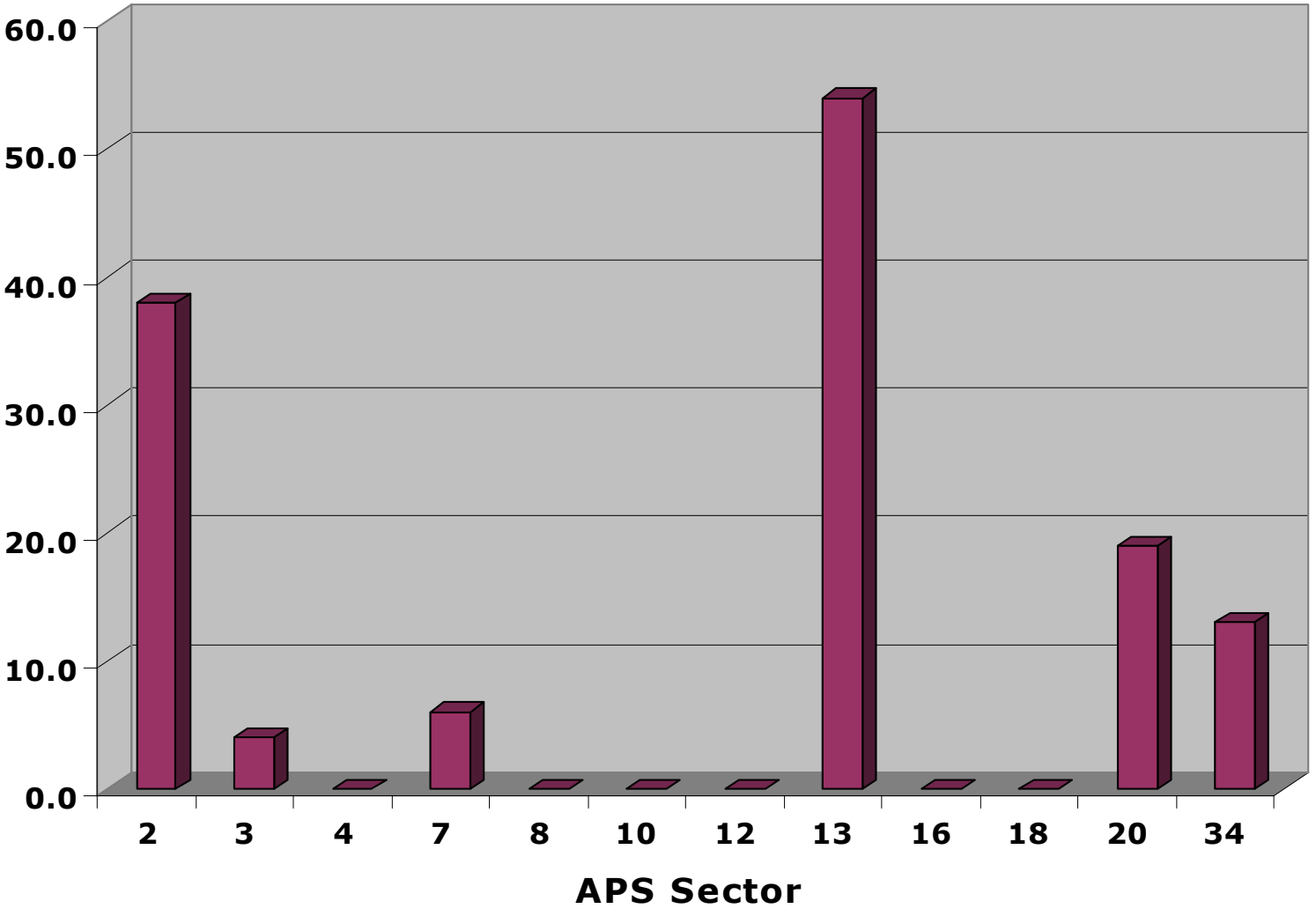


Coherent x-ray diffraction pattern of a single silver nanocube obtained by chemical synthesis, recorded at 34-ID-C.

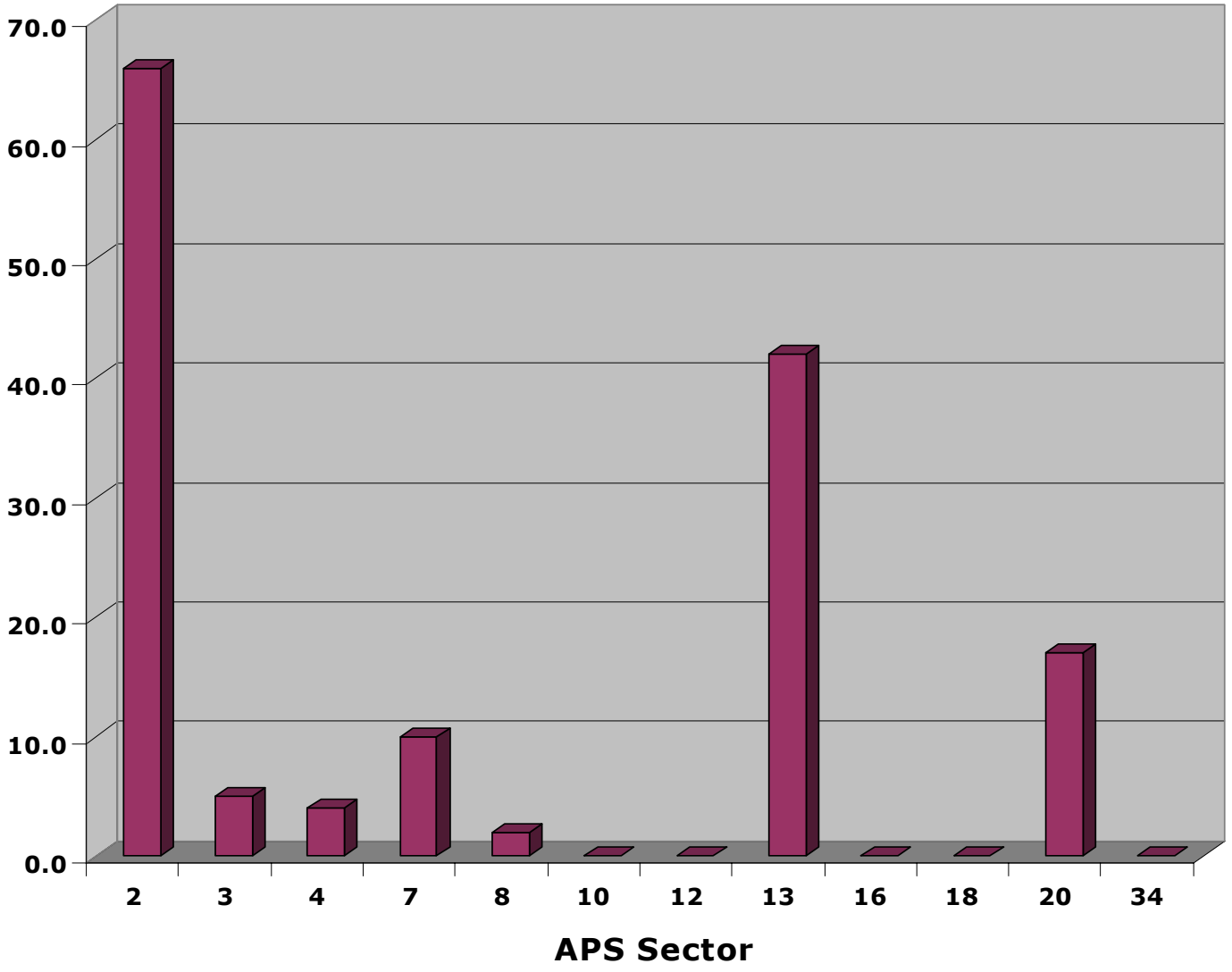
APS X-ray Microbeam Applications by Scientific Discipline



APS microbeam publications by sector (2002-2003)



Allocated GUPs by sector (2003)



New microbeam initiatives

- **Nanoprobe beamline (Nano-CDT, 26-ID)**
  - **Funded, MOU signed, construction underway**
- **Inelastic x-ray scattering beamline (IXS-CDT, 30-ID)**
  - **Funded, MOU signed, construction underway**
- **Micro XAS and Diffraction capability at BIOCAT**
  - **Under development (operational 2005)**
- **Environmental microspectroscopy beamline (EnviroCAT)**
  - **Proposed and partially-funded**
- **Multiplexed microfocusing beamline (UNI-CAT, 34-BM)**
  - **Partner User Proposal Letter of Intent submitted**
- **1-4 keV coherent imaging/scattering beamline (XOR)**
  - **Partner User Proposal in preparation**
- **Microfocus x-ray crystallography**
  - **Needed at APS (UC Review Committee/Janet Smith)**

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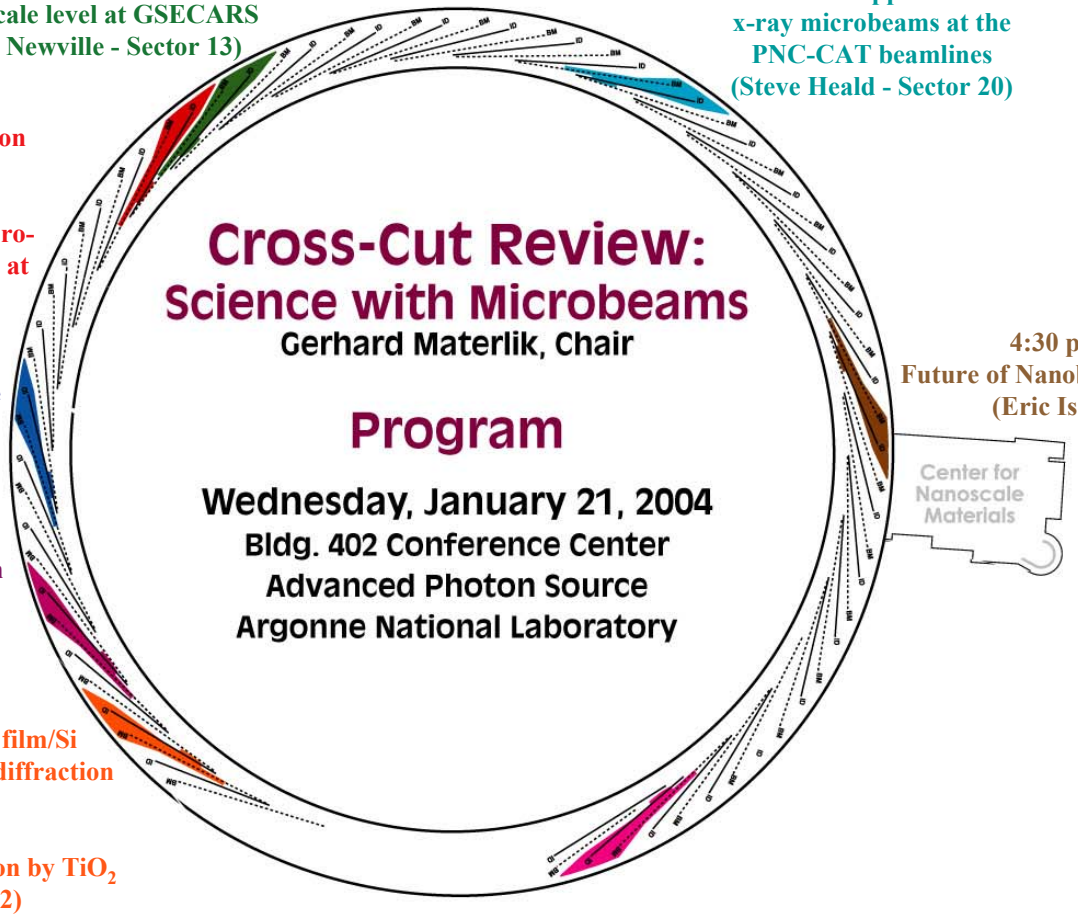

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